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A PHOTOMETRIC AND LEGIBILITY ASSESSMENT OF AEROSPACE OPTICS, IN--ETC(U)

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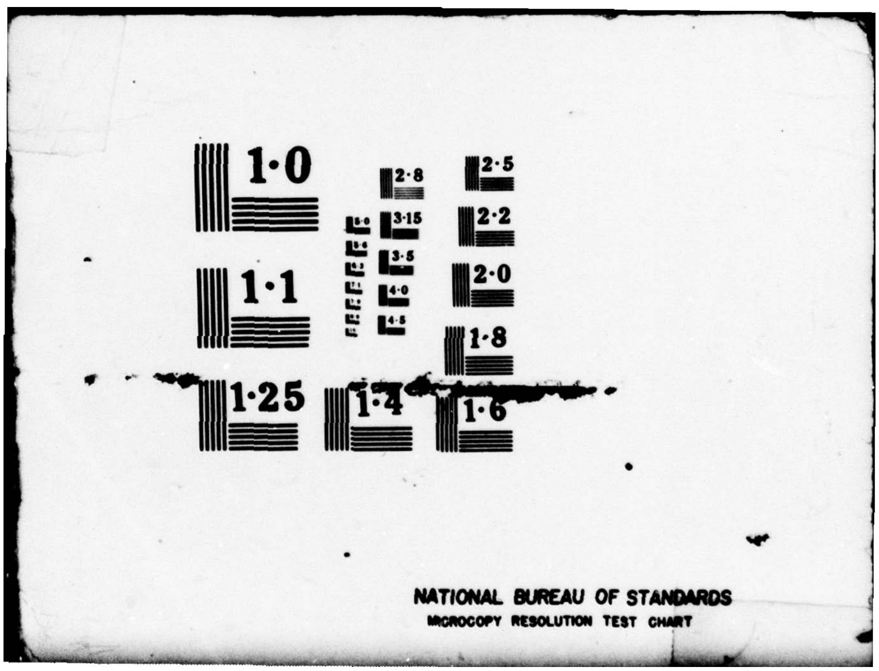
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Technical Note 2-79

A PHOTOMETRIC AND LEGIBILITY ASSESSMENT OF THE AEROSPACE OPTICS, INC. VIVISUN 20/20 DISPLAY

Harry R. Stowell
Alan M. Poston

January 1979
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U. S. ARMY HUMAN ENGINEERING LABORATORY

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An evaluation was conducted on an ~~Aerospace Optics, Inc.~~ annunciator display designed to be readable in direct sunlight. The color of the luminous legend was aviation red. The type of display evaluated is currently being used in commercial and military aircraft. Photometric and spectroradiometric measurements were taken in dark ambient lighting and in solar ambient lighting (direct sunlight) conditions. The red luminous legend was comfortably readable in direct sunlight even though the luminance contrast was below the 50 percent recommended by MIL-STD-1472B.

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CONTENTS

A PHOTOMETRIC AND LEGIBILITY ASSESSMENT OF THE AEROSPACE OPTICS, INC. VIVISUN 20/20 DISPLAY

INTRODUCTION

This effort was undertaken to ascertain the legibility characteristics of the Vivisun 20/20 display under conditions of:

a. Low ambient light.

b. Bright solar ambient light.

c. Night vision goggle use.

The amount of information that must be acquired visually by aircrew members in a modern aircraft is ever increasing. New systems are constantly being developed to provide information to improve operator performance, thereby improving mission effectiveness.

Electronic display systems have evolved to present a large variety of information to the aircrew member. Luminous source signals are one method used to present information on displays. The term luminous source signals, as used in this report, applies to self-illuminated signals in a display. Display system techniques of the luminous source type include:

a. Incandescent light, direct lighting, or light piped through fiber optics.

b. Liquid crystal panels.

c. Gas discharge panels.

d. LED's or EL mosaic displays.

e. CRT penetration displays.

Airborne displays must be legible both in low ambient lighting and in bright solar ambient lighting. Some displays are in color to code displayed information.

The problem in luminous source displays is the contrast required to provide comfortable, error-free legibility in solar ambient lighting.

Contrast is a measure of the luminance difference between the signal and the background as computed by the formula:

$$C = \left|\frac{L_1 - L_2}{L_1}\right| \times 100$$

where L_1 = the luminance of the bright area and L_2 = the luminance of the dark area.

A minimum contrast of 50 percent is recommended in MIL-STD-1472 (1) for legibility of information on a visual display. It is not difficult to obtain a 50 percent contrast ratio when information is presented on a display by a luminous source in low ambient lighting; however, in a high ambient lighting environment (direct sunlight) a 50 percent contrast ratio may be difficult to obtain due to "washout" effects. To enhance contrast in solar ambient lighting, solar reflection on the face of the display must be minimized. The spectral distribution of solar light reflected on the face of the display can be expected to modify the photocolorimetric characteristics of the luminous source and desaturation will result which makes color discrimination difficult, and sometimes impossible.

EVALUATION

The annunciator display evaluated is a Vivisun 20/20 that was on loan from Aerospace Optics Inc., Fort Worth, Texas. The evaluation was conducted mainly to obtain data on the characteristics of a colored luminous source display designed to be readable in solar ambient lighting (direct sunlight).

The legend on the annunciator consists of eight letters, "MSTR WARN," arranged in two rows (Figure 1). The face of the annunciator display appears as a dull black finish. The legend, which is red in this display, becomes visible when electrical power is applied. The luminous source is incandescent lamps, rated at 5 VDC, integrally mounted in the case. The red-colored luminous legend is produced by a special arrangement of light filters on the face of the display.

Apparatus

Photometric and radiometric measurements were taken with a Gamma Scientific, Inc., system. The components of the system are listed in the appendix.

A dark room, designed for photometric work at the US Army Human Engineering Laboratory (HEL), provided the dark ambient lighting environment.

A regulated DC power supply, with adjustable voltage output, was used for the electrical power to the annunciator display.

A digital read-out multimeter was used to measure the voltage to the lamps in the annunciator display.

Luminance Measurements—Dark Ambient Lighting

The annunciator display unit was placed on a test bench in the dark room and connected to the DC power supply. Test leads from the digital multimeter were connected to the lamp terminals. The power supply voltage was adjusted to 5 VDC.

A photometric microscope was coupled to the photometer and photomultiplier with a fiber optic probe. The photometer system was calibrated to a standard luminance source (photopic corrected). Ambient lighting in the dark room was measured at less than 10^{-5} foot-candles.

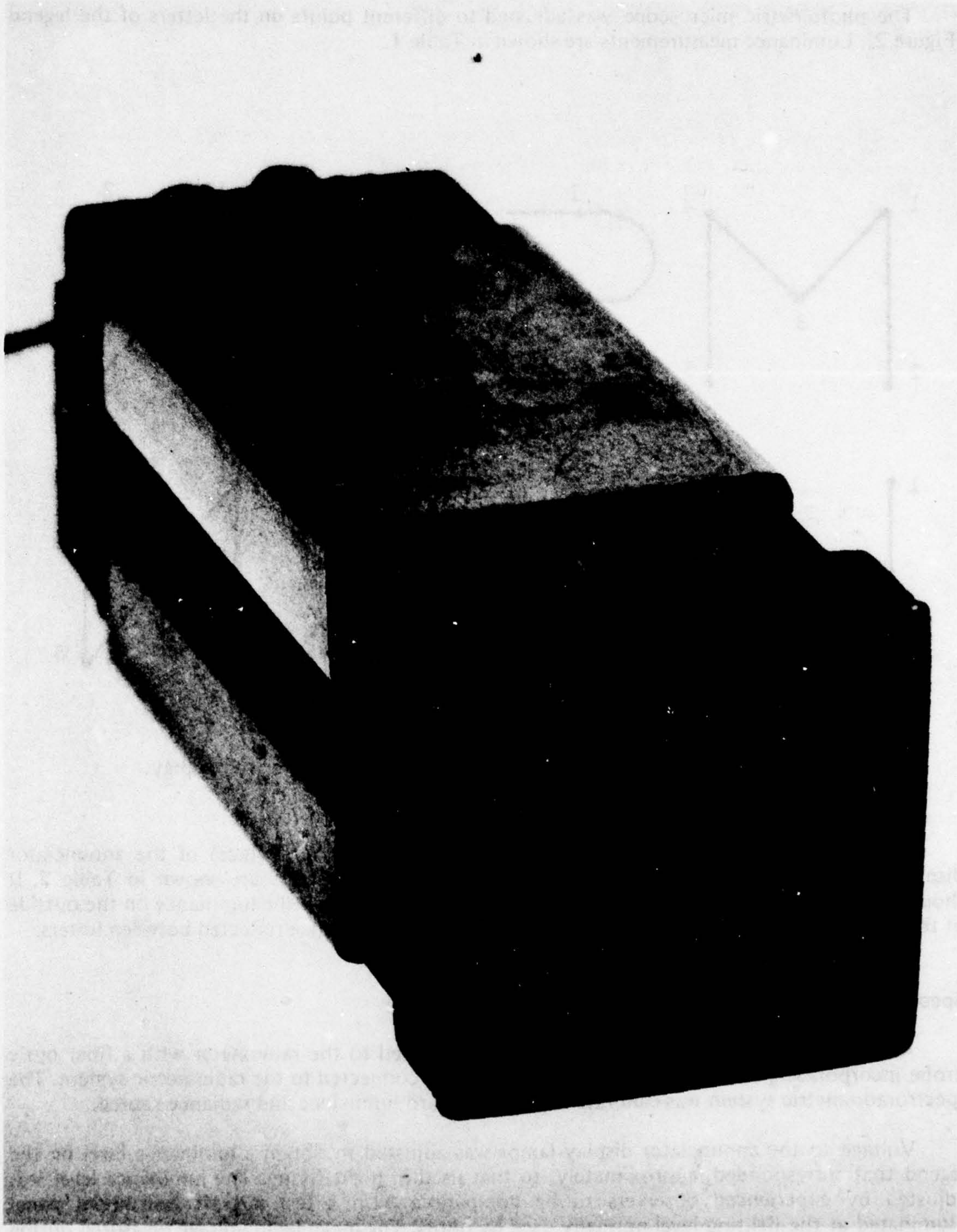

Figure 1. Aerospace Optics, Inc. Vivisun 20/20 annunciator display.

The photometric microscope was adjusted to different points on the letters of the legend (Figure 2). Luminance measurements are shown in Table 1.

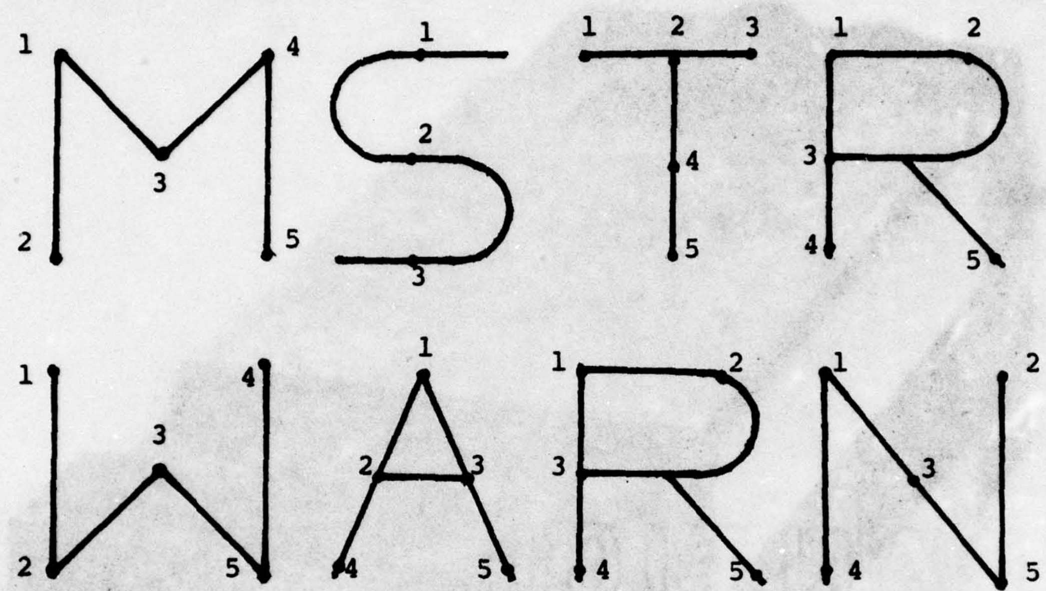

Figure 2. Spot measurement points on legend of the annunciator display.

Luminance measurements were also taken on the background (face) of the annunciator display with the legend illuminated at 5 VDC. These measurements are shown in Table 2. It should be noted that the luminance between letters is greater than the luminance on the outside of the display. This was probably caused by the combined luminance reflected between letters.

Spectroradiometric Measurements—Dark Ambient Lighting

A high-sensitivity photometric telescope was coupled to the radiometer with a fiber optic probe incorporating a slit exit aperature. A plotter was connected to the radiometric system. The spectroradiometric system was calibrated with a standard luminance and radiance source.

Voltage to the annunciator display lamps was adjusted to obtain a luminance level on the legend that corresponded, approximately, to that used in night flying. The luminance level was adjusted by experienced observers to be compatible with a test aircraft instrument panel illuminated at the lighting level normally used by pilots. The mean lamp voltage measured during these observations was 2.2 VDC. With 2.2 VDC at the lamps, the mean luminance on the legend was 12.4 foot Lamberts.

TABLE 1

Luminance (Photopic) Measurements On Legend of the Annunciator Display in Dark Ambient Lighting (Foot Lamberts)

Measurement Points[a]	(M)	(S)	(T)	(R)	Grand Mean
1	219	183	181	197	
2	154	203	230	189	
3	166	136	215	197	
4	243	191	191	150	
5	164	156	156	143	
	(W)	(A)	(R)	(N)	
1'	155	207	161	160	
2	230	143	162	147	
3	156	188	174	176	
4	239	221	233	230	
5	230	219	228	204	189

[a]See Figure 2 for measurement points.

TABLE 2

Luminance (Photopic) Measurement of Light Reflected On Background (Face) of Annunciator Display in Dark Ambient Lighting (Foot Lamberts)

Background Between Letters	Background Outside Edge	Grand Mean
1.3	0.6	
1.1	0.6	
1.1	0.9	
1.4	0.7	0.96

The photometric telescope was adjusted to different points on the letters of the legend. The scan control selector on the radiometric system was placed in the auto scan mode. Radiometric measurements were taken across the visible spectrum (400 to 700 nm) and were recorded with the plotter. Measurements were repeated with the scan selector in the manual mode. In the manual scan mode, readings were taken at 10 nm wavelength increments across the visible spectrum on the meter. The meter readings were compared with the tracing from the plotter, thus providing a means for checking the accuracy of the plotter.

Radiometric measurements were repeated on different letters on the legend to check the uniformity of the spectral distribution of the luminance. The spectral distribution appeared to be uniform across the legend.

Radiometric data were converted to photopic luminance by applying the luminous efficiency values (2) corresponding to radiance measurements across the visible spectrum. The photometric luminance values were plotted to show the spectral distribution of the luminance source of the legend. In dark ambient lighting, the luminance of the legend peaked in the red at approximately 620 nm (Figure 3).

Contrast

Contrast of the legend in dark ambient lighting was computed using the formula described in the Introduction. Using the grand mean luminance values in Tables 1 and 2, a contrast of 99.4 percent was obtained.

Night Vision Goggles (NVG)– AN/PVS-5

The annunciator display was viewed with the Army's NVG *to determine* if the legibility of the legend was satisfactory through the goggles.

Five individuals were used to do a subjective legibility test with the NVG. All subjects were experienced in the use of the goggles and in viewing illuminated displays on aircraft panels.

Each of the five subjects was, in turn, seated in front of the annunciator display at a 30-inch eye-to-display distance in a dark ambient lighting environment. Each subject was dark adapted 15 minutes before being instructed to fix the NVG to the eyes and focus the eyepiece on the annunicator display legend. After the subject finished adjusting the goggles, power to the annunciator lamps was turned off.

While seated in the dark ambient light, the subject was instructed to adjust the variable voltage control for the annunciator lamps for the minimum brightness level at which the legend was comfortably legible. The subject repeated the procedure several times with the voltage reading to the annunciator lamps being recorded for each individual trial. The mean voltage for all subjects was found to be 0.4 VDC.

With electric power to the annunciator lamps set at 0.4 VDC, photometric spot measurements were taken on the legend using the photometric microscope system. A number of spot measurements were taken on different letters in the legend. A mean luminance value of 1.5 x 10^{-5} foot Lamberts was computed from the different measurements. This mean luminance value shows a high correlation with the luminance value obtained for legibility on illuminated displays using NVG during a previous HEL investigation (3).

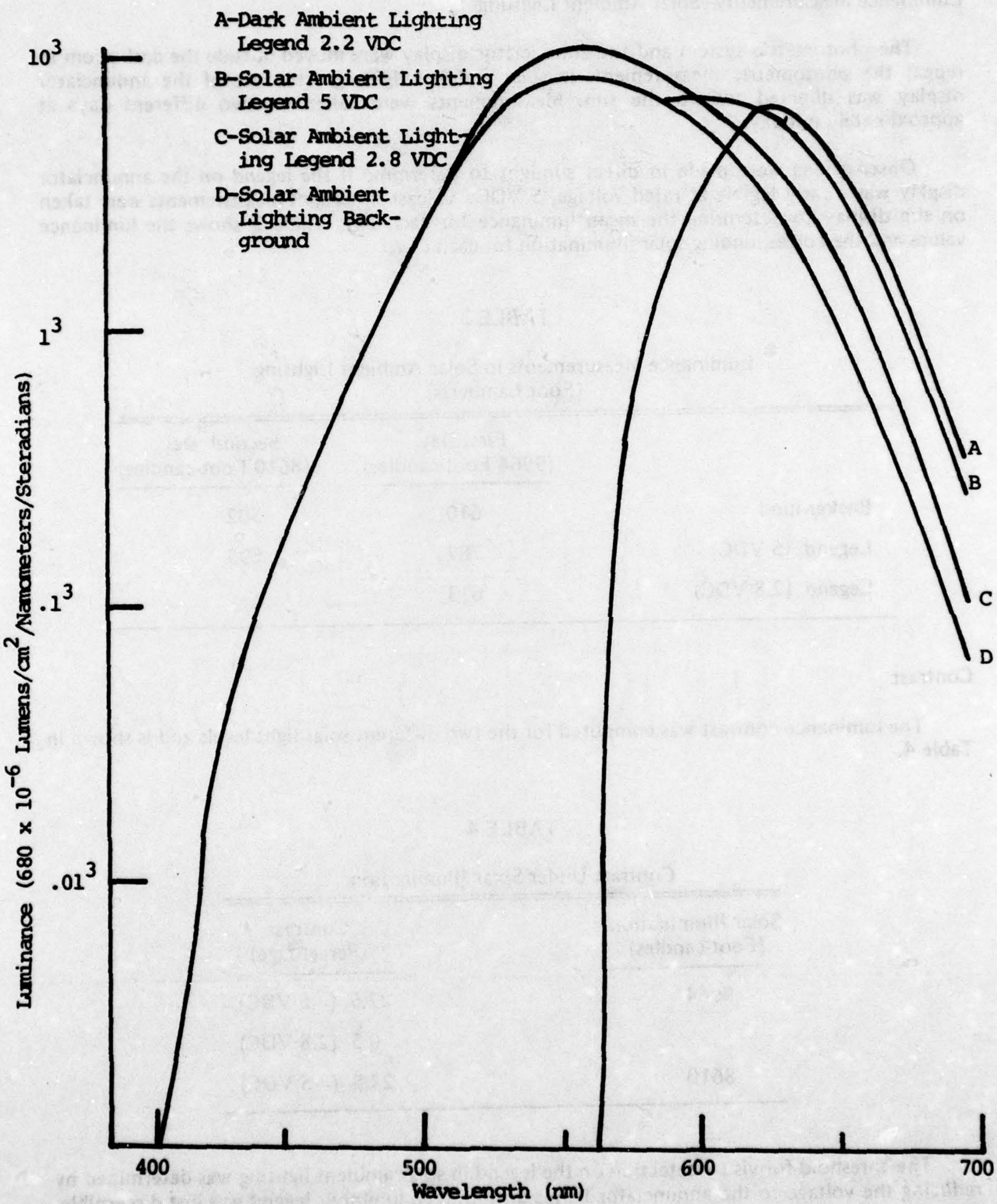

Figure 3. Photopic luminance distribution on the red legend and the background in solar lighting and in dark ambient lighting.

Luminance Measurements—Solar Ambient Lighting

The photometric system and the annunciator display were moved outside the dark room to repeat the photometric measurements in solar ambient lighting. The face of the annunciator display was directed toward the sun. Measurements were taken on two different days at approximately midday.

Observations were made in direct sunlight to determine if the legend on the annunciator display was clearly legible at rated voltage, 5 VDC. At least three spot measurements were taken on the display to determine the mean luminance for each day. Table 3 shows the luminance values and the corresponding solar illumination for each day.

TABLE 3

Luminance Measurements in Solar Ambient Lighting
(Foot Lamberts)

	First Day (9964 Foot-candles)	Second Day (8610 Foot-candles)
Background	610	502
Legend (5 VDC)	787	695
Legend (2.8 VDC)	613	–

Contrast

The luminance contrast was computed for the two different solar light levels and is shown in Table 4.

TABLE 4

Contrast Under Solar Illumination

Solar Illumination (Foot-candles)	Contrast (Percentage)
9964	22.5 (5 VDC)
	0.5 (2.8 VDC)
8610	27.8 (5 VDC)

The threshold for visual detection on the legend in solar ambient lighting was determined by reducing the voltage to the annunciator lamps until the red luminous legend was just discernible. The lamp voltage was 2.8 VDC at the threshold of detection. Due to the low contrast at this value (Table 4), legibility of the letters of the legend was not possible.

The light reflection characteristic of the background of the annunciator was computed using the photopic luminance measurements of Table 3 and was found to have a mean value of 6.0 percent.

Spectroradiometric Measurements—Solar Ambient Lighting

Spectroradiometric measurements were taken on the annunciator display across the visible spectrum (400-700 nm). The procedure used for taking radiometric measurements in solar ambient lighting was similar to that used in dark ambient lighting. Two sets of measurements were taken on the legend; one at 5 VDC and one at the threshold of detection, 2.8 VDC.

Radiometric measurements were also taken on the background (face) of the annunciator display. The radiometric data were converted to photopic luminance to show the spectral distribution of the reflected solar lighting on the background.

These curves, which are also plotted in Figure 3, show that the spectral distribution of the luminance of the legend has desaturated in bright solar lighting compared with the spectral distribution of the luminance of the legend in dark ambient lighting. It can be seen that in solar ambient lighting the curves peaked at approximately 550 nm while the peak was approximately 620 nm in dark ambient lighting.

RESULTS AND DISCUSSION

The red luminous legend on the Aerospace Optics, Inc., annunciator, Vivisum 20/20, was determined to be legible in both dark ambient lighting and in solar ambient lighting (direct sunlight).

The annunciator display was determined to be compatible with the use of the US Army Night Vision Goggles AN/PVS-5. The luminance level of the legend could be controlled to produce satisfactory legibility of the legend when the goggles were used.

The information obtained in this study indicates that legibility of information presented on a display with a colored luminous source is possible even though the luminance contrast may be considerably less than the 50 percent specified for legibility of display information in MIL-STD-1472. One problem, though, seems to be in preserving the purity of the color characteristics in a solar ambient lighting environment. The color characteristics of a colored luminous source may be modified and desaturated because of the spectral distribution of solar ambient lighting reflected on the luminous surface and on the background of the display system.

The annunciator display evaluated was designed to be readable in direct sunlight. This was accomplished mainly by a special process that was used on the face of the display to reduce the reflected solar lighting on the surface of the luminous source and on the background of the display.

A method needs to be developed to combine luminance and color of a luminous source display, which will obtain an index that will represent a measured value giving the impression corresponding to luminous contrast. This would provide a criterion for designing displays, as well as to provide a quantitative means to assess the legibility of a visual display system.

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1. Department of Defense. Human engineering design criteria for military systems, equipment and facilities. Military Standard, MIL-STD-1472B, Washington, DC, December 1974.

2. Kaufman, J.E. (Ed.). IES lighting handbook. (5th Ed.). New York: Illuminating Engineering Society. 1972. P. 3-5.

3. Stowell, H.R. An investigation of cockpit lighting for compatibility with use of night vision goggles, AN/PVS-5. Technical Memorandum 26-76, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, 1976.

APPENDIX

APPARATUS

Photometric measurements were taken in a light environmental mobile lab unit with a Gamma Scientific, Inc., photometric system consisting of equipment listed below:

Photometer– Model 2020
Photometer– Model 820A
Photometric Telescope– Model 700-2A
Photometric Telescope– Model 2020-31
Photometric Microscope– Model 700-10-2B
Photomultiplier Module– Model 820-18
Photopic Correction Filter– Model 820-18-1A and Model 2020-1A
Photomultiplier Detector– Model 2020-1
Cosine Receptor– Model 2020-3
Scanning Spectro Radiometer– Model 3000R
Luminance and Radiance Standard– Model 220-1